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Suicide and Ambient Temperature in East Asian Countries: A Time-Stratified Case-Crossover Analysis

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Abstract

Objectives: A limited literature base suggests that ambient temperature contributes to suicide, with studies typically focused on a single nation using temporal and spatial aggregated data. We evaluated an association between ambient temperature and suicide in multiple cities in three East Asian countries.

Methods: A time-stratified case-crossover method was used to explore the relationship between temperature and suicide, adjusting for potential time-varying confounders and time-invariant individual characteristics. Gender- and age-specific associations of temperature with suicide were estimated, as were interactions between temperature and these variables. A random-effects meta-analysis was used to estimate country-specific pooled associations of temperature with suicide.

Results: An increase in temperature corresponding to half of the city-specific standard deviation was positively associated with suicide in most cities, although average suicide rates varied substantially. Pooled country-level effect estimates were 7.8% (95% CI: 5.0, 10.8%) for a 2.3ºC increase in ambient temperature in Taiwan, 6.8% (95% CI: 5.4, 8.2%) for a 4.7ºC increase in Korea, and 4.5% (95% CI: 3.3, 5.7%) for a 4.2ºC increase in Japan. The association between temperature and suicide was significant even after adjusting for sunshine duration; the association between sunshine and suicide was not significant. The associations were greater among men than women in 12 of the 15 cities although not significant. There was little evidence of a consistent pattern of associations with age. In general, associations were strongest with temperature on the same day or the previous day, with little evidence of associations with temperature over longer lags (up to 5 days).

Conclusions: We estimated consistent positive associations between suicide and higher ambient temperature in three East Asian countries, regardless of country, gender, and age.

Introduction

Suicide is a crucial public health concern. In East Asia (a sub-region of Asia), suicide rates in South Korea, Japan, and Taiwan have increased to high levels. Suicide rates in South Korea had a notable spike from 13.6 per 100,000 in 1997 to 18.8 per 100,000 in 1998 in the wake of the economic crisis, with an even higher rate in 2010 (33.5 per 100,000). Japan experienced a sudden rise in suicide during the crisis from 15.2 per 100,000 in 1997 to 20.4 per 100,000 in 1998; this rate continues to this day (21.2 per 100,000 in 2010) (OECD 2011, 2012). The suicide rate in Taiwan also increased from 10.0 per 100,000 in 1998 to 19.3 per 100,000 in 2006 and then decreased to 16.8 per 100,000 in 2010 (Lee and Liao 2012). In comparison, suicide rates in Organisation for Economic Co-operation and Development (OECD) countries averages 11.3 per 100,000 in 2009 (OECD 2011).

Suicide is affected by various factors and by complex interactions between society and individuals (Chang et al. 2009; Durkheim 1951/1897; Juurlink et al. 2004; Qin et al. 2003). However, there is a consistent seasonal pattern (Ajdacic-Gross et al. 2010). Suicides peaked in spring or early summer in many European countries a century ago (Durkheim 1951/1897). Since then, many studies have suggested seasonal variation of suicide rates with a peak in spring or early summer, stronger in men than women, in the elderly compared with young people, and in suicide by violent methods (i.e., hanging, drowning, jumping, or cutting) than those by non-violent methods (i.e., ingestion of poisons, drugs, gases, or vapors) (Christodoulou et al. 2012; Lin et al. 2008; Reutfors et al. 2009). Interestingly, these patterns are observed across geographic regions, including European countries (Switzerland, Italy, Finland, and Romania), the United States, countries located in Southern hemisphere (Australia and South Africa; showing reciprocal

patterns with Northern hemisphere), and Asian countries (Japan, Hong Kong and China) that have different climate, economic status, and culture (Ajdacic-Gross et al. 2010; Christodoulou et al. 2012; Sun et al. 2011).

Studies designed to explain this pattern provided contradictory evidence of an association between ambient temperature and suicide, at least in part because the methods used had limited temporal and spatial variations or used aggregated data (Deisenhammer 2003; Dixon et al. 2007; Dixon and Kalkstein 2009; Ruuhela et al. 2009; Tsai 2010; Woo et al. 2012). Although a few studies endeavored to apply more appropriate statistical models that considered temporal variations and adjusted for seasonal trends using, for example, time-series regression models (Dixon et al. 2014; Kim et al. 2011; Lee et al. 2006; Likhvar et al. 2011; Lin et al. 2008; Page et al. 2007). Most of them covered a single nation and few took individual characteristics (gender or age) into account to compare associations of temperature with suicide between groups; those that did so generally used stratification approaches (Kim et al. 2011; Page et al. 2007).

To improve upon previous studies, we used a time-stratified case-crossover approach to adjust for time-invariant individual characteristics. This standardized method was applied across multiple locations in three countries of East Asia to examine the relationship between ambient temperature and suicide and to evaluate gender- and age- differences.

Methods

Study Area. We selected fifteen widely distributed major cities (over one million in 2010) from three countries, South Korea (six cities), Japan (six cities), and Taiwan (three cities) (Figure 1 and see Supplemental Material, Table S1). The study period varied across countries based on

access to mortality data: 19 years in Korea (1992–2010), 39 years in Japan (1972–2010), and 14 years in Taiwan (1994–2007). The neighboring countries, Korea and Japan, are distinctly seasonal; that is, temperature and relative humidity are high in summer, and winters are cold and dry. The climate of Japan, in contrast with Korea, varies between the northernmost and southernmost chain of islands; the difference of mean temperature between Sapporo (the northernmost city) and Fukuoka (the southernmost city) was 8.0 °C. The climate of Taiwan is sub-tropical with a mild winter and a year-round high humidity.

Suicide data. In all fifteen cities, deaths were considered to be suicide if the death was coded as intentional self-poisoning and self-harm from the *International Classification of Diseases, 8th–10th revisions, Clinical Modification* (ICD-8, ICD-9, and ICD-10). The ICD-8 and -9 codes used were E950.0–E958.9, and the ICD-10 codes used were X60–X84. Suicide data were obtained from Statistics Korea, Ministry of Strategy and Finance in South Korea, Ministry of Health, Labor and Welfare in Japan, and Department of Statistics, Ministry of Health and Welfare in Taiwan. Suicide cases were categorized by gender and by age groups, excluding cases younger than ten years. Age was categorized into three groups: 10–24 years (adolescents and young adults), 25–64 years, and over 65 years (older adults). Additionally, we collected suicide data at national levels to compare suicide rates across time periods between countries. City-specific population data were used to calculate yearly suicide rates in each city: five-year census with linear interpolation for Korea and Japan, and single-year for Taiwan. The population data were obtained from Statistics Korea, Ministry of Strategy and Finance in South Korea, Statistics Bureau, Ministry of Internal Affairs and Communications in Japan, and Department of Statistics, Ministry of the Interior in Taiwan.

Weather data. Hourly weather variables monitored at meteorological observatories in each city were obtained from the Korea Meteorological Administration, Japan Meteorological Agency, and Taiwan Central Weather Bureau. We calculated daily mean ambient temperature (°C), relative humidity (%), and atmospheric pressure (hPa), and the daily sum of sunshine duration (hours) at the city-level.

Statistical Analyses. Two stage analyses were conducted to examine the association between ambient temperature and suicide. At the first stage, we conducted city-specific analyses using a time-stratified case-crossover design that adjusts for seasonal patterns and long-term trends in the design itself (Barnett and Dobson 2010). Since development of the case-crossover design, the time-stratified approach has been recognized as being the least-biased method among referent (control) selection strategies (Basu et al. 2005; Janes et al. 2005). *A priori,* we split the time series into 56-day non-overlapping strata and compared differences in exposure (temperature) between case and control days within the same strata using a conditional logistic regression model. Each case was matched to 7 control days on the same day of the week during the 56-day stratum. Because each case served as its own control, case and control days were automatically matched with regard to age and gender. We used a 56-day (8 week) time period instead of a 28-day (4 week) time period to ensure there was a least one suicide during each time period in the smaller cities. In statistical models, the association between temperature and suicide was estimated adjusting for sunshine duration, relative humidity, atmospheric pressure, time trend (date of suicide; as a linear term), and month. A possible bias in temperature-suicide associations attributable to the longer stratum (Guo and Barnett 2015) was reduced by adjusting for the time trend and month in the models. In our sensitivity analyses, the difference of the risk estimates

between 28- and 56-day stratums was smaller in the model adjusting for month and date, compared with the difference of unadjusted estimates.

We specified two sets of models: one to estimate overall associations and the second with interaction terms to estimate gender- and age-specific associations. The case-crossover design cancels out potential confounding by time-invariant variables such as gender and age, there still is a need to adjust for these characteristics. By using interactions, we could estimate the gender- and age-specific associations between temperature and suicide, and test statistical significances for temperature-related gender- and age-differences. We modeled interactions between temperature and gender or categorical age group (10–24 years and 25–64 years, with ≥ 65 years as the reference category) using separate models.

Because the ranges of ambient temperature across three countries were different, we calculated the associations of temperature with suicide corresponding to a SD/2 unit increase of each city's mean temperature (standard deviation of the mean temperature divided by two) to show comparable results. Particularly, the range of mean temperature between winter and summer in the cities of Taiwan was narrower (from 17.2 °C to 28.9 °C) than those in the cities of Korea (from –0.1 °C to 25.2 °C) and the Japan (from –2.7 °C to 26.5 °C), and thus the units of temperature (SD/2) in Taiwanese cities were smaller (from 1.9 °C to 2.6 °C) than those in the cities of Korea (from 4.0 °C to 5.1 °C) and Japan (from 3.9 °C to 4.8 °C).

On the second stage, we used a meta-analysis with random effects to produce pooled associations. Because there was heterogeneity between city-specific associations in fifteen cities (I^2=40.8%, and p=0.02 derived from χ^2 test on Cochran's Q statistic) (Higgins and Thompson

2002), the meta-analysis was separately conducted in each country. Country-specific averages of the units of temperature (SD/2) were used to show the results. Similarly, the gender- and age-specific associations were pooled by country.

Sensitivity analyses. We performed several sensitivity analyses. First, we compared the association between temperature and suicide adjusting for month and date with the unadjusted association for temperature based on 28- and 56-day stratums in capital cities, to examine whether a 56-day stratum was appropriate. Second, we compared the association between temperature and suicide based on models with (main model) and without adjusting for sunshine duration. Simultaneously, we estimated associations between sunshine and suicide with and without temperature in the models. To examine the lag effects of temperature and sunshine on suicide, we specified two types of lag structures: single and moving average from event day to five days before. In addition, moving averages of sunshine were extended 10, 15, 20 days, and a 7-day moving average 90 days before the suicide were used on the assumption that a depressive mood in winter related to seasonal affected disorder (SAD) might have influenced spring suicides (Praschak-Rieder et al. 2008; Preti 1997).

We used SAS version 9.3 (SAS Institute) for the city-specific analyses and 'metafor' package of R version 3.0.1 (R foundation for Statistical Computing) for the meta-analyses. The alpha level used to define statistical significance was 0.05.

Results

Figure 2 shows yearly trends in suicide rates (national levels) across South Korea, Japan, and Taiwan. The suicide rates differed significantly over time and confirmed reported patterns: a

sharp increase in South Korea, a rise since 1998 in Japan, and a decline in 2007 after a steady increase in Taiwan. Suicide rates also differed by gender and age across the three countries (see Supplemental Material, Figure S1 and S2). For example, suicides by elderly adults in South Korea increased five-fold between 1992 and 2010, while those in Japan decreased consistently. In addition, male and female suicides increased in South Korea and Taiwan whereas female suicides in Japan have been stable. The seasonal peak of suicide was in spring and early summer (March–June), but was extended until July in two Taiwanese cities (Taipei and Kaohsiung) (see Supplemental Material, Figure S3). There was also a consistent pattern of suicide with day of the week across the cities—more suicides on Mondays or Tuesdays and less suicides on Saturdays or Sundays (see Supplemental Material, Figure S4). Climate features between the study cities varied by location—annual average of temperature ranged from 8.8 °C (Sapporo) to 25.3 °C (Kaohsiung) (Table 1). Relative humidity was similar between cities of Korea and Japan, humid in summer but dry in winter, while Taiwanese cities located at sub-tropical region were humid all year round (see Supplemental Material, Table S2).

An association between temperature and suicide. Figure 3 presents country- and city-specific associations between temperature and suicide, showing that higher ambient temperature was associated with a significant increase in suicide in 12 of the 15 cities. The highest country-specific pooled association for temperature was 7.8% (95% CI: 5.0, 10.8%) for a 2.3 °C increase in ambient temperature in Taiwan; 6.8% (95% CI: 5.4, 8.2%) for a 4.7 °C increase in Korea; and 4.5% (95% CI: 3.3, 5.7%) for a 4.2 °C increase in Japan. There was a 7.8% increase in suicides for each SD/2-increase in daily mean temperature (2.3 °C) in Taiwan. The range of city-specific associations with temperature was broader in Korea (4.8–9.1%, 6 cities) and Japan (2.7–6.4%, 6

cities) than in Taiwan (7.0–9.0%, 3 cities). Associations based on models with and without adjustment for sunshine duration were comparable (see Supplemental Material, Table S3). There was a significant positive association between sunshine duration and suicide in two cities before adjustment for temperature (see Supplemental Material, Table S3) but there were no significant associations after adjustment for temperature, including sunshine duration during single-day lag periods up to 5 days (see Supplemental Material, Figure S5) and based on models with moving averages up to 90 days (see Supplemental Material, Figure S6).

Subgroup analyses. Figure 4 and Supplemental Material, Table S4 show gender and age specific associations between temperature and suicide by cities. Associations were stronger among men than women in 12 of 15 cities (although not significant), with the exception of Busan, Taipei, and Fukuoka (the latter being the only city where there was a significant difference by gender). In contrast, there was little evidence of associations with age. Associations were stronger in those ≥ 65 years than the other age groups in 9 of 15 cities, but were only statistically significant in three cities (Seoul, Busan, and Tokyo). The association in Seoul was significantly stronger among those ≥ 65 years than in those 10–24 or 25–64 years, but in Busan and Tokyo the association was significantly weaker among those 25–64 years than in those ≥ 65 years.

Lag structure. Compared with longer single-day lag periods (up to 5 days), associations with suicide were strongest for temperature on the same day (lag = 0) in most cities, with the exceptions of Busan, Nagoya, and Fukuoka, where associations were slightly stronger with temperature on the previous day (lag = 1) (see Supplemental Material, Figure S7). The associations were 7.8% (95% CI: 4.8, 10.9%) for a 4.0 °C increase in Busan, 4.2% (95% CI: 0.9,

7.7%) for a 4.2 °C increase in Nagoya, and 5.9% (95% CI: 1.6, 10.4%) for a 3.9 °C increase in Fukuoka. In general, associations decreased as the number of lag days increased. Associations with moving average temperatures up to 5 days showed less variation than associations based on single-day lags (see Supplemental Material, Figure S8).

Discussion

The aim of this study was to examine the relationship between suicide and ambient temperature across multiple sites with large discrepancies in suicide rates. Higher temperatures were associated with significantly higher risks of suicide in most cities. In addition, the associations between temperature and suicide did not differ significantly by gender and age. These findings suggest that in East Asia, suicide is positively associated with ambient temperature, regardless of country, gender, and age.

Previous studies reported some evidence supporting a positive association between high ambient temperature and suicide (Christodoulou et al. 2012; Deisenhammer 2003; Deisenhammer et al. 2003; Kim et al. 2011; Likhvar et al. 2011; Page et al. 2007). For example, two studies in East Asia using a time series analysis found a 1.4% increase in suicide associated with each 1 °C increase in daily mean temperature in South Korea and increases in suicide associated with temperature on the same day (lag = 0) for all regions in Japan (Kim et al. 2011; Likhvar et al. 2011). In addition, a study in Austria reported a 12% increase in suicide risk associated with a 10 °C increase in temperature, using hierarchical logistic regression (Deisenhammer et al. 2003). A study in England and Wales using a threshold model showed that

each 1 °C increase in mean temperature above 18 °C was associated with a 3.8% increase in suicide (Page et al. 2007).

Possible mechanisms for temperature to trigger suicide. There are no agreed-upon biological mechanisms to explain the association between ambient temperature and suicide. It has been hypothesized that higher suicide rates in the spring and early summer may reflect seasonal variation in the serotonin system, a neurotransmitter that may influence impulsiveness and aggression, possibly leading to suicide (Luykx et al. 2013; Mann 2013).

The plasma L-tryptophan is a serotonin precursor and its lower concentration is associated with major depression disorders (Ogawa et al. 2014). An ecological study in Belgium (Maes et al. 1995) showed that seasonal variation of concentrations of the plasma L-tryptophan (collected by monthly blood samples of healthy volunteers) were inversely correlated with the seasonal variation of the number of violent suicides. Also, they reported that the concentrations were negatively associated with ambient temperature.

Decreased level of the serotonin transporter in the midbrain or prefrontal cortex (PFC) was suggested to be associated with depressed suicides (Mann 2013; Miler et al. 2013). Praschak-Rieder et al. (2008) reported that serotonin transporter bindings, when measured at several brain regions of healthy subjects, were lower in spring and summer than fall and winter and were negatively correlated with daily sunshine duration. This suggests a possible relationship between seasonal variation of serotonin transporters and suicide.

Because sunshine has been reported to be associated with alterations in the serotonergic system (Lambert et al. 2002; Praschak-Rieder et al. 2008; Sansone and Sansone 2013) or suicide

rate in Australia or in Austria (Lambert et al. 2003; Vyssoki et al. 2014), we analyzed whether sunshine duration was associated with suicide. We found no evidence of an association between sunshine duration and suicide in our study cities, regardless of the lag period.

Subgroups. The literature suggests the associations between temperature and suicide are generally stronger in men and older adults. A population-based ecological study in South Korea (Kim et al. 2011) reported a higher risk of suicide with higher temperature among men than women, as well as higher among those ≥ 65 years than in those < 65 years. Another population-based study in Italy using monthly data (Preti and Miotto 1998) reported that seasonality of suicide was more prevalent among older men and women (≥ 65 years) than younger people (14–24 or 25–64 years) and that the simple correlation between violent suicide and temperature was higher in men than women. In our study, we found similar patterns with previous studies for gender, with the associations between suicide and temperature generally higher in men than women (in 12 of 15 cities); however, gender was not significantly associated with suicide. In addition, age differences were not statistically significant except in three big cities (stronger association in those ≥ 65 years compared with the other age groups in Seoul; and stronger associations in those ≥ 65 years than those 25–64 years in Busan and Tokyo). The age difference in big cities probably resulted from larger sample sizes.

Strengths. To our knowledge, this is the first study of suicide and temperature using a time–stratified case–crossover analysis, covering multiple locations in multiple countries adjusting for seasonal variations and accounting for time-invariant individual characteristics. Moreover, we covered long-term study periods from 14 years (Taiwan) to 39 years (Japan). Most previous

studies examining the association between suicide and ambient temperature were conducted in a single country using aggregated data due to the small number of suicide cases, although a few used more advanced statistical methods (Kim et al. 2011; Lee et al. 2006; Likhvar et al. 2011; Lin et al. 2008; Page et al. 2007). In this study, we tested the statistical significance of the associations between suicide and temperature by gender and age group incorporating interaction terms into the models. Previous studies using time-series analysis chose the stratification method to compare the association by gender or age (Kim et al. 2011; Page et al. 2007). The model with interactions in our study allowed statistical comparison of the associations by gender or age, yielding parameter estimates of the difference based on the whole data.

Limitations. Nevertheless, this study had some limitations. First, generalization of our results might be limited because the study area only covered countries in East Asia. Although we found consistent associations between high ambient temperatures and suicide regardless of country, further studies including other countries, particularly with different suicide rates, are needed to replicate the hypothesis. Second, our findings were estimated on the basis of a linear association between suicide and temperature. Although higher temperature was positively associated with suicide, there were regional differences in whether suicide risks increased during extreme high temperature periods (Dixon et al. 2014; Kim et al. 2011; Likhvar et al. 2011; Page et al. 2007). Further studies with a wider range of regions are needed to assess suicide risks associated with extreme high temperature. Third, we could not consider air pollution in our analyses. Studies recently reported an association between air pollution (particulate matter) and suicide or depression (Kim et al. 2010; Lim et al. 2012). Evaluating interactions between ambient temperature, air pollution and suicide would be a new challenge to study. Finally, it was

impossible to consider depression in our analyses because of difficulties in collecting the data. Depression is a risk factor of suicide (Qin et al. 2003) and is associated with season, e.g. seasonal affective disorder (Magnusson 2000). Assessing an association between mental illness and temperature would give a better understanding of the impact of temperature on suicide.

Conclusions

Our study suggests that higher ambient temperatures may increase suicidal behaviors. This study provides an important consideration for suicide prevention. With respect to climate variability and change, research and policy interests have focused on heat-related deaths due to physical illness, but our findings support the need for research on the potential effects of a changing climate on mental illnesses as well.

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Table 1. Suicide rate and daily average of total suicide and weather in fifteen cities.

Country	City	Study period	Total Suicide cases	Suicide rate (per 100,000)	Daily suicide cases (mean ± SD)	Temperature (ºC) (mean ± SD)	Sunshine (hour) (mean ± SD)	Humidity (%) (mean ± SD)	Atmospheric Pressure (hPa) (mean ± SD)
Korea	Seoul	1992-2010	28 134	14.9	4.1 ± 2.8	12.8 ± 10.1	5.4 ± 3.7	62.9 ± 14.6	1016.2 ± 8.1
	Busan	1992-2010	12 922	19.0	1.9 ± 1.6	14.9 ± 8.0	6.2 ± 3.9	63.7 ± 18.5	1015.5 ± 7.2
	Inchoen	1992-2010	8 889	18.8	1.3 ± 1.3	12.5 ± 9.7	6.2 ± 3.9	67.9 ± 14.3	1015.9 ± 8.1
	Daegu	1992-2010	7 631	16.3	1.1 ± 1.2	14.4 ± 9.3	6.1 ± 3.8	59.4 ± 15.5	1016.4 ± 7.7
	Daejeon	1992-2010	4 622	17.3	0.7 ± 0.9	13.0 ± 9.8	5.9 ± 3.7	67.1 ± 13.5	1016.3 ± 8.0
	Gwangju	1992-2010	3 826	14.5	0.6 ± 0.8	14.1 ± 9.3	5.7 ± 3.7	67.6 ± 12.7	1016.2 ± 7.9
Japan	Sapporo	1972-2010	11 598	18.0	0.8 ± 1.0	8.8 ± 9.5	5.6 ± 3.7	69.7 ± 10.8	1012.5 ± 7.1
	Sendai	1972-2010	5 671	16.6	0.4 ± 0.7	12.3 ± 8.2	6.1 ± 3.5	71.1 ± 13.4	1014.1 ± 6.8
	Tokyo	1972-2010	60 184	18.4	4.2 ± 2.3	16.2 ± 7.8	6.4 ± 3.5	62.2 ± 15.4	1013.8 ± 6.8
	Nagoya	1972-2010	15 231	18.2	1.1 ± 1.1	15.7 ± 8.4	6.7 ± 3.5	66.7 ± 12.7	1014.7 ± 6.5
	Osaka	1972-2010	24 955	24.1	1.8 ± 1.4	16.8 ± 8.3	6.3 ± 3.5	63.6 ± 10.9	1015.0 ± 6.7
	Fukuoka	1972-2010	9 066	18.7	0.6 ± 0.8	16.8 ± 7.8	6.1 ± 3.7	68.1 ± 11.6	1015.4 ± 7.0
Taiwan	Taipei	1994-2007	9 480	10.8	1.9 ± 1.6	23.2 ± 5.3	4.0 ± 3.7	76.1 ± 9.1	1012.5 ± 6.8
	Taichung	1994-2007	3 350	9.7	0.7 ± 0.8	23.7 ± 4.7	5.8 ± 3.5	74.8 ± 7.7	1002.6 ± 5.6
	Kaohsiung	1994-2007	5 049	13.2	1.0 ± 1.1	25.3 ± 3.8	6.1 ± 3.4	76.0 ± 7.1	1012.0 ± 5.4

Figure Legends

Figure 1. Geographical locations of the study area (A), six cities in South Korea (B), six cities in Japan (C), and three cities in Taiwan (D).

Figure 2. Yearly trend of suicide rates at national levels. The suicide rates differed significantly over time: a sharp increase in South Korea, a sudden rise since 1998 in Japan, and a decline in 2007 after a steady increase in Taiwan. Suicide and population data were obtained from Statistics Korea, Ministry of Strategy and Finance in South Korea, Ministry of Health, Labor and Welfare (for suicide) and Statistics Bureau, Ministry of Internal Affairs and Communications (for population) in Japan, and Department of Statistics, Ministry of Health and Welfare (for suicide) and Department of Statistics, Ministry of the Interior (for population) in Taiwan.

Figure 3. Country- (squares) and city- (circles) specific associations of temperature on the same day with suicide. [a]ΔT indicates a SD/2 unit increase of each city's mean temperature (standard deviation of mean temperature divided by two). [b]Percent change (%) indicates suicide risk corresponding to a SD/2-increase in mean temperature adjusting for sunshine duration, relative humidity, atmospheric pressure, time-trend (date of suicide), and month. The country-specific pooled associations (squares) were calculated by a random-effect meta-analysis.

Figure 4. Associations between temperature and suicide by gender (A) and age group (B). City- (circles) and country- (squares) specific associations of temperature with suicide are indicated by percent change (PC) of suicide risk corresponding to a SD/2-increase (standard deviation divided by two) in mean temperature. The abbreviations stand for male (M), female (F), 10-24 years (Y), 25-64 years (M), 65 years and over (E).

Figure 1.

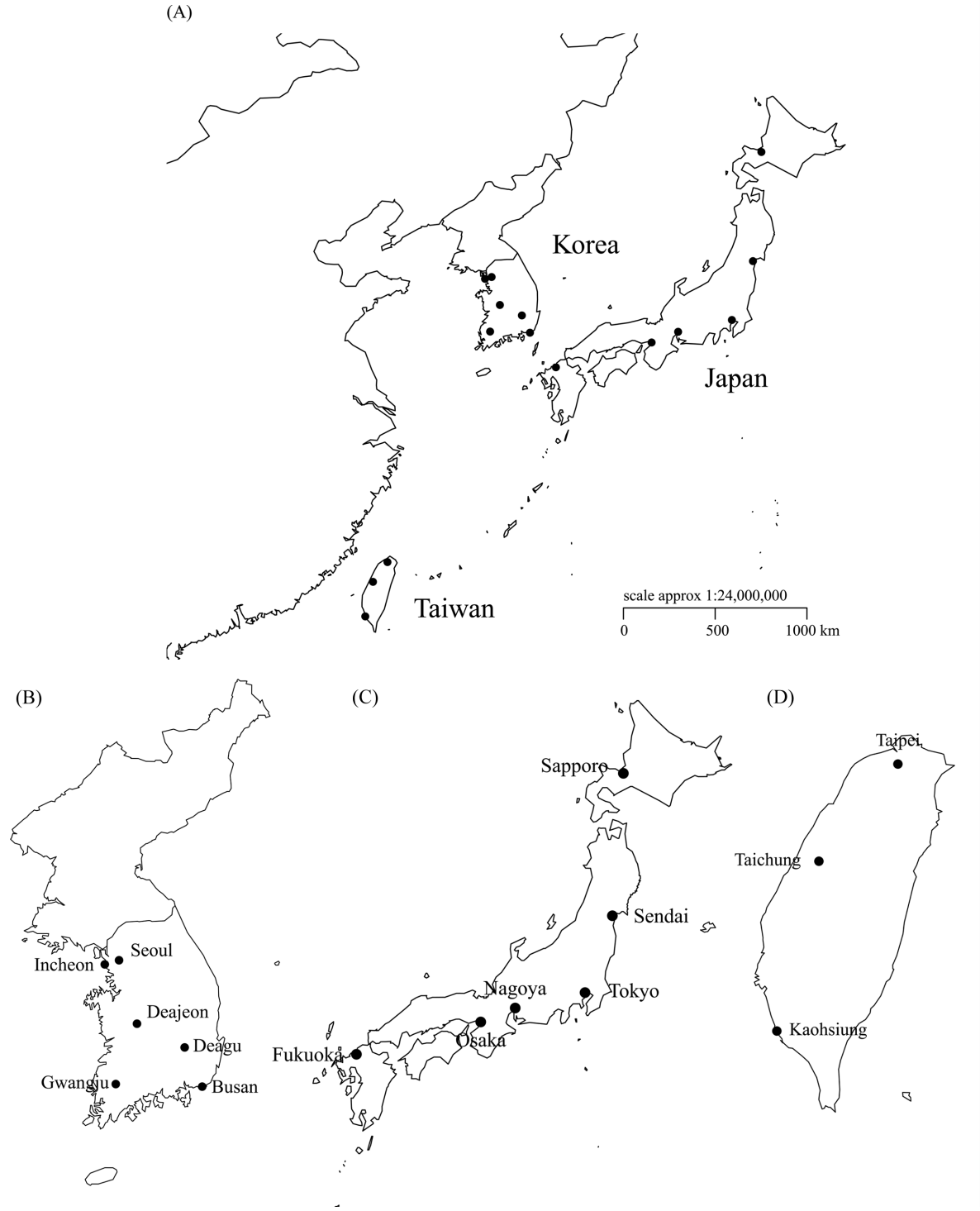
(A)
Korea
Japan
Taiwan
scale approx 1:24,000,000
0
500
1000 km
(B)
Seoul
Incheon
Deajeon
Deagu
Gwangju
Busan
(C)
Sapporo
Sendai
Nagoya
Tokyo
Osaka
Fukuoka
(D)
Taipei
Taichung
Kaohsiung

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Figure 2.

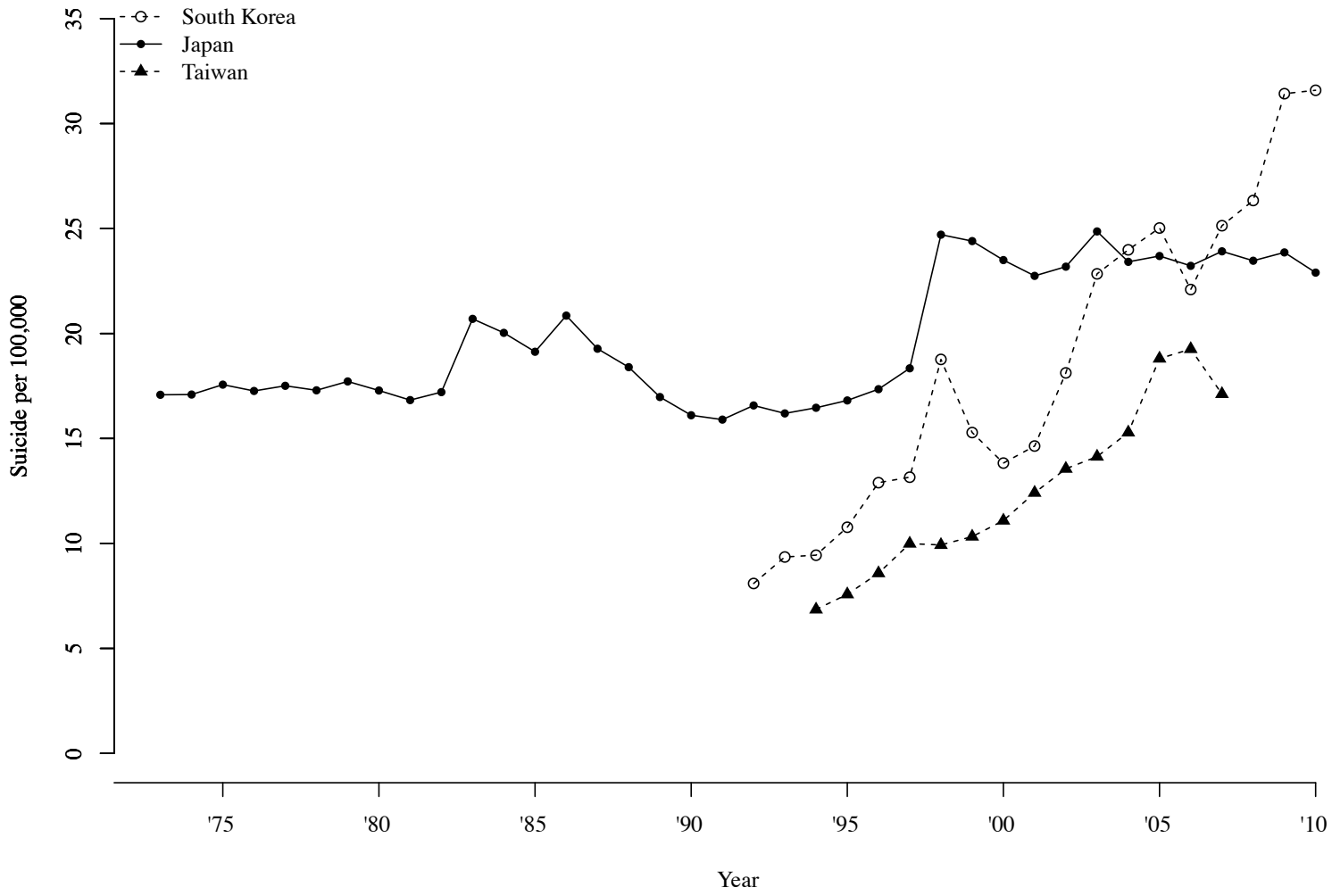

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Figure 3.

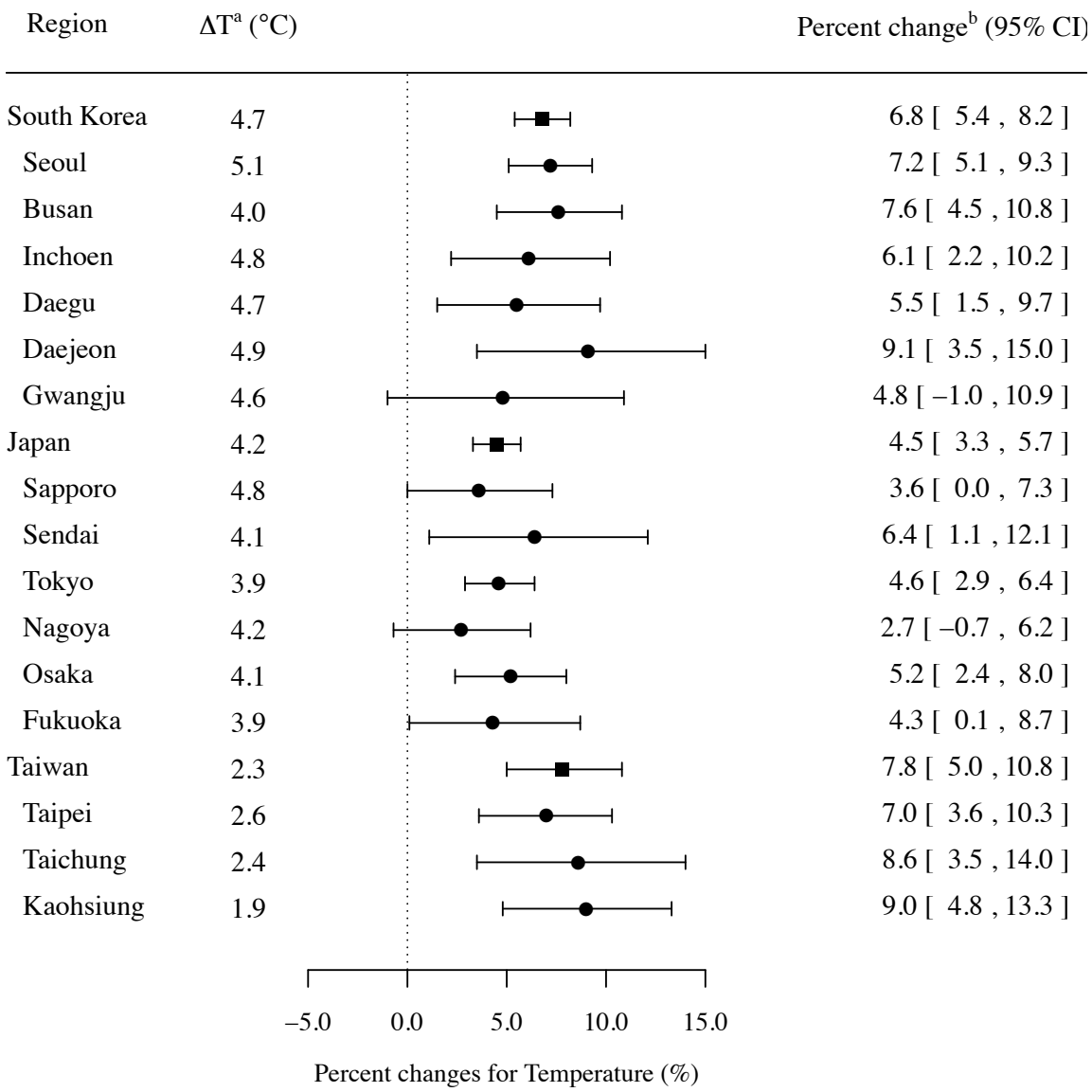

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Figure 4.